Foods of Rodents in the Hamakua District, Hawaii[1]

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ABSTRACT: The food habits of *Rattus exulans, R. rattus, R. norvegicus,* and *Mus musculus* captured in sugar cane fields, in gulches adjacent to cane fields, and in areas of human habitation, were determined from the stomach contents of 1205 rodents collected in 12 consecutive monthly samples. In cane fields the diet of *R. exulans* and *R. rattus* was primarily the internodes of sugar cane, while *Mus* fed principally on insects and grass seeds. In gulches *R. exulans* subsisted mainly on sugar cane, but *R. rattus* fed heavily on grass stalks and fruits. *Mus* from this habitat consumed *kukui* nuts and insects to a large extent, while the few *R. norvegicus* found here took a variety of foods. The foods of *R. rattus* and *R. norvegicus* captured near human habitations consisted mainly of garbage, other waste materials, and mixed livestock rations.

NUTRITION IS a primary requirement for the support of animal populations, and its quality is considered by some ecologists to be the ultimate factor which controls the growth or decline of such populations. Hence, knowledge of food habits is an important element in the understanding of rodent ecology. In Hawaii early investigations by Caum (1922), Spencer (1938), and Doty (1945) provided basic information for their programs directed toward control of rodents which damage sugar cane.

The present investigation was undertaken as part of extensive research on the reservoirs and vectors of bubonic plague. Three species of rats, *Rattus rattus* (L.), *R. norvegicus* (Berkenhout), and *R. exulans* (Peale), and a mouse, *Mus musculus* L., make up the rodent complex of the Hamakua district on the northeast coast of the island of Hawaii. Because plague bacilli have been detected many times in humans, rodents, and rodent fleas in the area extending from the village of Kukuihaele on the west to that of Paauhau on the east, trapping effort for rodent collections was concentrated within that area.

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DESCRIPTION OF SELECTED HABITATS

Sugar Cane Fields

Permanent trap lines were established in sugar cane fields which varied in crop age from recently planted seedlings to mature cane, ready for harvest. In fields of young cane the area between the rows is bare of weeds and other cover. After a time, the ground is often overgrown by seed-producing forbs and grasses, and so littered by the fallen leaves and stalks of cane that penetration of the field is nearly impossible.

Gulches

Trap lines were also established in two gulches, Ouhi gulch near Paauhau and an unnamed gulch adjacent to cane fields near Waipio Valley. The section of Ouhi gulch studied

separates a cane field from a waste grassland. Throughout the area from which rodents were trapped, large Java plum trees (*Eugenia cumini*) and *kukui* trees (*Aleurites moluccana*) form a forest-like overstory. In the understory there are *ti* plants (*Taetsia fruticosa*), coffee shrubs (*Coffea* sp.), and a restricted variety of other species. The floor of this gulch is formed of large exposed boulders and is subject to occasional, torrential runoff.

Thick stands of false ironwood (*Casuarina* sp.) predominate in the gulch near Waipio Valley. Scattered growths of *kukui* and guava (*Psidium guajava*) trees, and of *ti*, as well as patches of palm grass (*Setaria palmifolia*) and panicum grasses (*Panicum purpurascens, P. maximum*) are found along the slopes. The floor of this short gulch is not eroded and is densely matted with *honohono* (*Commelina nudiflora*), panicum, and palm grasses.

Areas of Human Habitation

In residential areas, consisting mainly of rural villages, traps were placed in or about houses, storage sheds, garages, stone fences, hedges, orchards, pig and cattle pens, and chicken coops.

METHODS AND PROCEDURES

The stomachs of rodents caught by snap-traps were removed in the laboratory and preserved in 70% isopropyl alcohol. Contents were weighed to the nearest 0.1g on a triple beam balance, and then sorted and spread evenly in a petri dish. A grid of 1 cm^2 units, drawn on a card, was placed beneath the dish to aid in estimating the percentages of different items found in the stomach. Weights and percentages of these items were the only quantitative measurements taken.

Examination of the food materials was made with the aid of a dissecting microscope. Items not easily distinguished were placed on a piece of cheesecloth and washed with a jet of water. Hulls of certain grass seeds and stalks were washed and dried to make identification possible. Identifications were frequently made by direct comparison with sample items gathered from the various trapping areas. (A check list of botanical names of plants used by rodents as food will be found at the end of this article.)

Because coconut was used as bait in snap-traps, stomachs of rodents which had fed exclusively on coconut were not included in the tabulations. Rodents caught in a 3.5-acre tract of waste grassland adjacent to a sugar cane field were treated as being caught in the cane field, because stomach examinations showed contents similar to rats caught in cane fields and also because of the small sample size of rats captured in the grassland.

Trapping was conducted once a month for a four-day period from July 1963 to June 1964.

RESULTS

Cane Fields (see Table 1)

Rattus norvegicus: Only one specimen was obtained from the cane fields; insect fragments were the only dietary item. This animal was not included in Table 1.

Rattus exulans: The principal food of cane field *R. exulans* was sugar cane, which occurred in 68.2% of the rats and amounted to 67.2% of the food materials. Foods of secondary importance were seeds and stalks of grasses, found in 21.3% of the animals and constituting 15.1% of the volume. Insects, including adults, larvae, and egg masses, contributed 6.0% to the food materials.

In most cases, identification of these insects was possible only as ground-inhabiting Coleoptera or Orthoptera because the hard chitinous exoskeleton was masticated into fine fragments beyond exact recognition. However, the larvae of craneflies (Tipulidae) and small moths (Tineidae), and the adults of the sugar cane mealy bug (*Saccharicoccus sacchari*) and of the sugar cane weevil (*Rhabdoscelus obscurus*), and the eggs of the mealy bug were identified below the ordinal level. Larvae and egg masses were often found mixed with other food items, but no relationship between these insects and any particular food item was found.

The pulp and seeds of guava fruits were utilized by 4.8% of the animals and formed 3.5% of the volume. Other food materials included *kukui* nuts, animal flesh, earthworms, slugs, and materials which could not be identified. These items amounted to 8.1% of the volume.

TABLE 1

STOMACH CONTENTS OF RODENTS CAPTURED IN CANE FIELDS

FOOD ITEMS	*Rattus exulans* NO. EXAMINED: 359 FREQUENCIES NO.	%	VOL. %	*Rattus rattus* NO. EXAMINED: 34 FREQUENCIES NO.	%	VOL. %	*Mus musculus* NO. EXAMINED: 345 FREQUENCIES NO.	%	VOL. %
Fruits and berries	17	4.8	3.5	4	11.8	5.7	2	0.6	0.3
Grass (seeds)	50	14.0	8.6	6	17.6	11.9	132	38.3	32.0
Grass (stalks)	26	7.3	6.5	3	8.8	5.5	8	2.3	3.0
Insect	68*	19.1	6.0	5*	14.7	4.4	56	16.2	7.4
Insect (egg mass)							86	24.9	25.5
Insect (larvae)							31	9.0	5.9
Sugar cane	243	68.2	67.2	21	61.8	59.7	25	7.2	9.8
Nuts	3	0.8	0.7				5	1.4	1.8
Unidentified material	21	5.9	5.9	5	14.7	11.9	24	6.9	10.9
Animal flesh	3	0.8	0.5	1	2.9	0.8	5	1.4	1.8
Other invertebrates (earthworms and slugs)	10	2.8	1.0				7	2.0	1.6

* Includes adults, larvae, and egg masses.

TABLE 2

SUMMER AND WINTER FEEDING PATTERN OF *R. Exulans* CAPTURED IN CANE FIELDS

FOOD ITEMS	SUMMER (APRIL–SEPTEMBER) NO. EXAMINED: 169 FREQUENCIES NO.	%	VOL. %	WINTER (OCTOBER–MARCH) NO. EXAMINED: 190 FREQUENCIES NO.	%	VOL. %
Fruits and berries	10	5.9	3.6	9	4.7	3.8
Grass (seeds)	35	20.7	14.1	13	6.8	3.6
Grass (stalks)	13	7.7	6.4	13	6.8	6.2
Insects	41*	24.3	9.6	25	13.1	2.2
Sugar cane	94	55.6	56.2	147	77.4	77.7
Nuts				3	1.6	1.2
Unidentified materials	14	8.3	8.3	7	3.7	3.9
Animal flesh				1	0.5	0.6
Other invertebrates (earthworms, slugs, etc.)	7	4.1	1.7	4	2.1	0.8

* Includes adults, larvae, and egg masses.

Although heavy feeding on sugar cane was evident throughout the year, its use during the winter period increased 21.8% in frequency and 21.5% in volume. During the summer there was an increase in the consumption of grass seeds and insects (see Table 2). No seasonal changes were observed in the use of fruits. The other food items were too infrequently observed to allow seasonal comparisons.

Rattus rattus: The pattern of food preferences was similar to that of *R. exulans.* Sugar cane was the primary diet; 61.8% of the animals fed on cane which formed 59.7% of the volume. Grass seeds and stalks were of considerable importance to 26.4% of *R. rattus* and these foods amounted to 17.4% of the diet by volume. The seeds and stalks of *Panicum maximum, P. purpurascens,* and *Setaria palmifolia* were preferred to other available grasses by both *R. rattus* and *R. exulans.*

Fruits, mainly guavas, and a few berries of poha (*Physalis peruviana*) and of nightshade (*Solanum nigrum*), constituted 5.7% of the

TABLE 3

STOMACH CONTENTS OF RODENTS CAPTURED IN GULCHES

FOOD ITEMS	*Rattus exulans* NO. EXAMINED: 146			*Rattus rattus* NO. EXAMINED: 123			*Mus musculus* NO. EXAMINED: 25			*Rattus norvegicus* NO. EXAMINED: 3		
	FREQUENCIES NO.	%	VOL. %	FREQUENCIES NO.	%	VOL. %	FREQUENCIES NO.	%	VOL. %	FREQUENCIES NO.	%	VOL. %
Fruits and berries	18	12.3	9.4	41	39.8	30.5				1	33.3	33.3
Grass (seeds)	4	2.7	1.7	14	13.6	10.1	6	24.0	14.6			
Grass (stalks)	30	20.5	17.7	28	27.2	23.2						
Insects	20*	13.7	2.9	5*	4.8	2.2	6	24.0	5.6			
Insects (egg mass)							4	16.0	14.0			
Insects (larvae)							2	8.0	0.6			
Sugar cane	76	52.0	51.8	8	7.8	6.3				1	33.3	21.6
Nuts	8	5.5	6.2	12	11.6	10.7	5	20.0	23.3			
Unidentified materials	11	7.5	7.2	14	13.6	11.5	7	28.0	41.9	2	66.7	45.0
Animal flesh	5	3.4	3.0	6	5.8	5.0						
Other invertebrates (earthworms, slugs, etc.)				1	1.0	0.3						

* Includes adults, larvae, and egg masses.

R. rattus diet. Insects and unidentified materials occurred in uniform frequencies, but the latter items were greater in volume. Trace amounts of rodent flesh and pelage were found in a single specimen. *Kukui* nuts and the lower invertebrates were absent from the diets of *R. rattus* from cane fields. Because of the small sample size, no comparison between summer and winter feeding pattern was made.

Mus musculus: Insects, primarily egg masses, and seeds of *Digitaria henryi, Paspalum conjugatum,* and *Panicum maximum* comprised 38.8% and 32.0% respectively of the food materials of *Mus.* Sugar cane, an important source of food for *R. rattus* and *R. exulans,* was of little importance to this species. Only 7.2% of the mice fed on cane and it formed a mere 9.8% of the volume. Unidentified materials constituted 10.9% of the volume. Other food items such as fruits and berries, nuts, animal flesh, and lower invertebrates amounted to 5.5% of the diet. No apparent differences in the feeding pattern between winter and summer were observed.

Gulches (see Table 3)

Rattus norvegicus: The Norway rat was the least abundant rodent in the gulches; only three were captured. Fruit of the Java plum was the only food item in one specimen, materials in a second rat could not be identified, and the third had eaten 65% sugar cane along with 35% unidentified materials.

Rattus exulans: The major food source of the gulch-inhabiting *R. exulans* was sugar cane. This item occurred in 52.0% of the rodents and formed 51.8% of the food materials. Grass stalks were taken by 20.5% of the rats and amounted to 17.7% of the volume.

In the gulches many animals fed on *kukui* nuts, guava fruits, and berries. These items formed 15.6% of their diets. Although insects were found in 13.7% of the animals, they amounted to only 2.9% of the volume. The remaining 11.9% of the food materials consisted of grass seeds, animal flesh, and unidentified matter.

Rattus rattus: The preferred foods of *R. rattus* in the gulches were seeds and stalks of grass, and guava fruits. These items constituted 33.2% and 30.5%, respectively, of their diet and occurred in 40.8% and 39.8%, respectively, of the animals. Gulch *R. rattus* also fed more on *kukui* nuts than on sugar cane. Nuts were consumed by 11.6% of the animals and amounted to 10.7% of the volume, while cane was eaten by 7.8% of the rodents and amounted to 6.3% of the volume.

Insects appeared in 4.8% of the animals, and contributed 2.2% to the volume. Unidentified materials, animal flesh, and traces of lower invertebrates comprised the remaining 16.8% of the dietary items.

Mus musculus: Insects continued to be one of the major food sources of 48% of the mice taken in this habitat and constituted 20.2% of their diet. *Kukui* nuts, the other item of major importance, though absent from the diet of cane field *Mus,* were consumed heavily by 20.0% of the mice and amounted to 23.3% of the volume.

Grass seeds also were of considerable importance, with 24.0% of the mice feeding on them to form 14.6% of the diet. However, a large portion of foods eaten (41.0% by volume), were materials that could not be identified.

Absent from the diet of *Mus* were fruits and berries, grass stalks, sugar cane, animal flesh, and lower invertebrates, all of which appeared in the cane field *Mus.*

Residential and Other Areas Associated with Human Habitation (see Table 4)

Rattus norvegicus: The diet of Norway rats taken from areas associated with human habitation included materials (60.1% by volume) that could not be identified. This predominance of unidentified materials was attributed to the nature of the food sources (i.e., garbage, chicken feeds, hog swill, garden vegetables, etc.) associated with this habitat. Norway rats showed no marked preference for other food items, which they ate in considerable variety.

Rattus rattus: Of the food materials of *R. rattus* taken from this area 40% consisted of materials which could not be identified. Grass stalks continued to be of importance, forming 20.9% of the diet. Although more of the rats had fed on guava fruits than on sugar cane, these items differed only slightly in volume. Guava was consumed by 18.2% of the rats and it contributed 10.7% to the total volume, while sugar cane was consumed by 12.7% of the animals and amounted to 11.1% of the volume. Other dietary items consisting of grass seeds, insect forms, nuts, and animal flesh formed the remaining 17.0% of the food materials.

Stomach Parasites

During the course of this project, nematodes were frequently found in the stomach in rats, but infrequently in *Mus.* These nematodes were so numerous in some rats that their stomachs were filled with these parasites. As many as 32 nematodes were found in a stomach. Parasitism was highest among *R. rattus,* with 113 of 312 (36.2%) infested, and lowest among *Mus,* with 26 of 720 (3.6%) infested. Nematodes occurred in 116 of 615 (18.7%) *R. exulans* and 13 of 88 (14.8%) *R. norvegicus.* Nematodes of the genus *Protospirura* were identified from all four species of rodents and a specimen of *Physaloptera* was found in *R. rattus.*

TABLE 4

STOMACH CONTENTS OF RODENTS ASSOCIATED WITH HUMAN HABITATION

	Rattus rattus NO. EXAMINED: 121			*Rattus norvegicus* NO. EXAMINED: 49		
	FREQUENCIES		VOL.	FREQUENCIES		VOL.
FOOD ITEMS	NO.	%	%	NO.	%	%
Fruits and berries	22	18.2	10.7	4	8.2	5.2
Grass (seeds)	11	9.1	6.0	5	10.2	7.4
Grass (stalks)	29	24.0	20.9	3	6.1	5.3
Insects	10*	8.3	2.9	1	2.0	0.1
Sugar cane	15	12.4	11.1	5	10.2	7.7
Nuts	8	6.6	5.8	3	6.1	5.9
Unidentified materials	49	40.5	40.2	27	55.1	60.1
Animal flesh	5	4.1	2.3	6	12.2	5.7
Earthworms				1	2.0	0.1
Corn				1	2.0	2.4

* Includes adults, larvae and egg masses.

DISCUSSION AND CONCLUSIONS

Caum (1922) found that sugar cane by itself was an inadequate diet for rats, for those he had kept on a strict cane diet showed symptoms of malnutrition and partial starvation. Yet in the Hamakua study sugar cane was the preferred food of *R. exulans* in cane fields as well as in gulches and of *R. rattus* in cane fields. *R. rattus* in gulches did not display this strong attraction toward sugar cane, presumably because other preferred foods were more easily available.

A study of rats inhabiting gulches adjacent to cane fields on the Island of Kauai (Spencer, 1938) showed results similar to mine: sugar cane comprised 26% of the food materials of the gulch-inhabiting *R. exulans,* but was absent from the diet of *R. rattus* in the same habitat.

Caum (1922) hypothesized that rats feed on sugar cane only incidentally or in order to expose and feed upon the caneborers infesting the stalks. These hypotheses seem very unlikely, however, as the data showed that too many rats were attracted to sugar cane and consumed too much of it for it to be an incidental food item; moreover very few insects of any kind were found with the ingested sugar cane.

Doty (1945) stated, "the availability of protein foods is the limiting factor controlling the increase of rats in cane fields and adjacent waste areas." Protein foods such as insects, lower invertebrates, and animal flesh were available, with insects forming a large part of the diet of *Mus* in the selected cane fields. Rats in the same habitat did not utilize these sources of protein as much as did *Mus* but, instead, fed heavily on grass stalks, which are also a source of crude protein. Hosaka (1957) reported average crude protein (green weight basis) of *Panicum maximum* as 1.2% and of *P. purpurascens* as 1.8%. My findings indicate that the various rodents tend to satisfy their nutritional requirements in different ways.

In cane fields rodent populations are not necessarily limited only by the availability of protein foods, but also by other environmental conditions, and perhaps by behavioral and physiological traits as well. The diets, and hence the prosperity, of rats depend, therefore, largely upon the materials available to them, which in turn may influence their choice of habitat, and upon their abilities to exploit these materials.

In cane fields *Mus* and *R. exulans* were the predominant species and *R. rattus* was present in small numbers, but only a single *R. norvegicus* was found. In gulches *R. exulans* and *R. rattus* were the prominent species. In areas of human habitation only *R. rattus* and *R. norvegicus* were examined, primarily to augment inadequate samples from the other habitats. *R. rattus* thrived in gardens and orchards, but *R. norvegicus* was abundant only near houses, livestock pens, poultry coops, or slaughter houses. These differences in the species composition of rodents within each of the three habitats may reflect differences in utility, preference, or availability of food sources as well as in selection of cover. Eskey (1934) captured 56% *R. rattus,* 36% *R. norvegicus,* and 8% *R. exulans* inside and within 50 ft of buildings; 64% *R. rattus,* 16% *R. norvegicus,* and 20% *R. exulans* were caught 51–500 ft from buildings; and 72% *R. rattus,* 9% *R. norvigicus,* and 19% *R. exulans* were trapped more than 500 ft from buildings.

Spencer (1938) found that *R. rattus* preferred wild foods and *R. norvegicus* domestic foods, and that *R. exulans* was intermediate in preference between wild and domestic foods, but inclined toward domestic foods. However, the present findings show that *R. exulans* prefers wild foods; *R. rattus* uses both wild and domestic types, but is inclined toward wild foods, and *R. norvegicus* prefers domestic foods. Calhoun (1962) found that Norway rats took garbage more readily than the commercially prepared food left in feed troughs of penned rats, showing prominent selection between kinds of domestic foods. These findings indicate that while *R. rattus* can easily adapt itself to most habitats, *R. norvegicus* in particular and *R. exulans* to a lesser degree are rather limited in their use of habitats and food sources. Schein and Orgain (1953) found that rats generally preferred foods that promoted gain in body weight and avoided foods not useful to them. Under present conditions in the Hamakua district, the most versatile of the three species of rats appears to be *R. rattus,* which utilizes a wide variety of domestic and wild food sources and adapts itself readily to field habitats as well as to domestic environments. *R. exulans,* however, is restricted to field and gulch environments and depends wholly on

LIST OF IDENTIFIED PLANTS USED BY RODENTS AS FOOD

PLANT	PARTS EATEN
GRAMINEAE	
Paspalum conjugatum (Hilo grass)	stalks and seeds
Setaria palmifolia (palm grass)	stalks and seeds
Panicum maximum (Guinea grass)	stalks and seeds
Panicum purpurascens (para grass)	stalks and seeds
Digitaria henryi (Henry crabgrass)	seeds
Saccharum officinarum (sugar cane)	internodes
CYPERACEAE	
Kyllinga pumila (sedge)	seeds
LEGUMINOSAE	
Desmodium sp. (beggar weed)	pea pods
COMMELINACEAE	
Commelina nudiflora (*honohono*)	stem
COMPOSITAE	
Emilia flammea (Flora's paint brush)	seeds
MYRTACEAE	
Psidium guajava (guava)	seeds and fleshy pulp
Eugenia cumini (Java plum)	fleshy pulp
PASSIFLORACEAE	
Passiflora sp. (Passion fruit)	seeds
SOLANACEAE	
Physalis peruviana (*poha*)	whole berry
Solanum nigrum (night shade or *popolo* berry)	whole berry
ROSACEAE	
Rubus rosaefolius (thimble berry)	whole berry
EUPHORBIACEAE	
Aleurites moluccana (*kukui* nut)	nut

the food sources available in these habitats. This dependence on wild foods has developed this rat into an efficient feeder on grass seeds and stalks, sugar cane, and a wide variety of other wild foods. The scarcity of Norway rats in the fields and gulches may be simply because their adaptation to survival in the wild has become impaired. This may mean that they are no longer able to utilize successfully a diet that is relatively poor in protein because of changes in ability to select foods, changes in quality of foods available, or changes in internal physiology.

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